Lean vs. Agile Supply Chain: The Effect of IT Architectures on Supply Chain Capabilities and Performance

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Abstract

The widespread use of information technology (IT) has changed the nature of supply chain management. However, it is still unclear whether different IT infrastructure design may affect supply chain capabilities and firm performance. In this study, we investigated the impacts of a supply chain's IT architecture, which could be integration-based or standardization-based, on supply chain capabilities and firm performance. We also examined the effects of lean and agile supply chain strategies. We tested our research model against data collected from 162 companies, 97 based in China and 65 in Taiwan. Our findings indicate that firms with different supply chain strategies focus on different aspects of IT architectures. In addition, supply chain capability is an enabler to enhance supply chain performance through well-suited supply chain IT.

Keywords: Agile strategy, IT architectures, IT integration, IT standardization, lean strategy, supply chain capabilities

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Introduction

Both internal and external supply chain integration are necessary to the development of supply chain capabilities and performance (Flynn et al., 2010; Zhao et al., 2011). Information technology (IT) is an important tool which supports supply chain integration via information sharing and in the planning, coordination, and control of the production process at every level (Stevens, 1989). Strong IT capabilities enhance material, information, and financial flow, improve product development, and increase delivery speeds and the reliability and flexibility of the delivery process (Boyer and Lewis, 2002; Carter and Narasimhan, 1996). Fragmented IT infrastructures can hinder supply chain integration by impeding information flow and reducing coordination between supply chain partners (Barua et al., 2004). An integrated IT infrastructure with unified data standards and integrated applications enables information flow and coordination between departments, across geographic areas, and among value network partners (Broadbent et al., 1999b). Modern supply chain management is built on an efficient IT platform. Researchers have found that IT has an effect on supply chain capabilities and firm performance (Sambamurthy et al., 2003; Pavlou and El Sawy, 2010; Tarafdar and Qrunfleh, 2017). However, no prior research has investigated whether this effect is contingent on supply chain strategies.

The introduction of IT has transformed the performance of organizational supply chains (Banker et al., 2006; Rai et al., 2012). It is revolutionizing the ways a firm connects to its partners, manages its operations and responds to its customers (Rai et al., 2006). However, investments in supply chain IT may no longer generate competitive advantage because they have become a routine affair. Hence, realizing value from supply chain IT is a challenge for most firms (Sambamurthy et al., 2003). Facing ubiquitous digitization, faster pace of new product introductions, increased globalization and demanding customers, firms have to astutely manage their supply chain IT. Hence, good IT supply chain design is vital to gaining competitive advantage in the present business climate. This research studied the impact of supply chain IT designs on firms' operational and financial performance.

Indeed, prior research has examined the impacts from functionalities of varied supply chain IT, such as EDI (Mukhopadhyay et al., 1995) and Rosettanet (Malhotra et al., 2005; 2007). However, recent literature studying organizational impacts of IT argues for a focus on alternate antecedents, such as the actual usage of IT (Devaraj and Kohli, 2003; Mishra et al., 2007; Mishra and Agarwal, 2010). Moreover, there is a broad recognition that IT may not directly lead to firm performance. Instead, researchers have proposed that various capabilities mediate the impacts of IT on firm performance (Sambamurthy et al., 2003; Pavlou and El Sawy, 2010). Given that, recent research has identified dynamics to create IT-enabled capabilities across supply chain domains, such as manufacturing (Banker et al., 2006), operations (Setia et al., 2013), and logistics (Rai et al., 2012). Although prior research focused on the role of IT functionalities and IT usage in creating such capabilities, there is a general recognition that to build such supply chain capabilities, firms have to go beyond investing in IT functionalities or enhancing the usage of acquired IT.

Supply chain management emphasizes decreasing costs and increasing flexibility to improve performance in challenging business environments (Lee, 2004); in a volatile market, priorities are shifted, allowing the supply chain network to mount an efficient and effective response to the circumstances (Schonberger and Brown, 2017; Chiang et al., 2015). In supply chain management, lean and agile supply chain strategies focus on different supply chain capabilities to accomplish service goals. A lean supply chain strategy helps eliminate all waste and achieve efficient production, while an agile supply chain strategy enhances firms' capability to deal with rapid environmental change by, for example, satisfying customer needs quickly.

Research has started to focus on the designs of acquired information systems to create superior IT architectures. Recent research has also conceptualized IT architectures as antecedent to supply chain capabilities. For example, Rai and Tang (2010) studied the impacts of IT platform integration and IT platform reconfiguration on varied supply chain capabilities. Although their research has brought IT architectures into prominence, research in this domain is in its infancy. A key question in particular remains unanswered: what IT architectures can build high performing supply chain capabilities? To address this gap, we developed a mid-range theory to investigate the effects of the two dimensions of IT architectures— IT integration and IT standardization—on building such capabilities (Ross et al., 2006).

Limited research has been conducted on how firms choose better IT architectures for different supply chain strategies. Our goal was to assess if different supply chain strategies have different impacts on IT architectures. We collected data from manufacturers in the Greater China area (China and Taiwan), which is a major center of manufacturing. The results of our research have shown that firms with different supply chain strategies tend to focus on different styles of IT architecture—either standardization or integration. IT standardization works better with a lean supply chain strategy while IT integration supports an agile supply chain strategy. Second, supply chain capabilities impact the relationship between IT architectures and firm performance. These results may be of use to firms that wish to determine an IT architecture for their supply chain strategy that could be an antecedent to their supply chain capabilities.

This paper is organized in the following manner: Section 2 covers theoretical background; in this section, we develop our hypotheses regarding the interrelationship between these constructs. Section 3 contains profiles of the samples, explains the strategies used in our analysis, and describes the measures applied in this study. The results are summarized in Section 4, while Section 5 includes discussion of their theoretical and managerial implications. In Section 6, we present our conclusions and suggest possibilities for further research.

Theoretical Background and Development of the Hypotheses

To better illustrate the proposed relationships of our research model (see Fig. 1) in a nomological network, we've adopted the capability building perspective to explain the effect of IT architectures on firm performance.

IT Architectures

Although it is well-recognized that IT architectures form the backbone for various business functions of a firm, prior literature has given varied dimensions and definitions of the construct. Often, IT architectures are conceptualized as IT infrastructure. Broadbent et al. (1999b) defined IT infrastructure as "the base foundation budgeted-for IT capability (both technical and human), shared throughout the firm in the form of reliable services, and centrally coordinated" (p. 160). Similarly, Byrd and Turner (2000) proposed that "IT infrastructure is the shared IT resources consisting of a technical physical base of hardware, software, communication technologies, data and core applications and a human component of skills, expertise, and competencies, commitments, values, norms and knowledge that combine to create IT services that are typically unique to an organization." (p. 172). In addition, Ross (2003) argued that "IT architecture is the organizing logic for applications, data and infrastructure technologies, as captured in a set of policies and technical choices, intended to enable the firm's business strategy." Henderson and Venkatraman (1994) referred to varied aspects of IT architecture such as the "technical IT infrastructure, comprising the choices pertaining to applications, data, and technology, and the human IT infrastructure, which comprises the choices pertaining to experience, commitments, and norms of the IT personnel delivering products and services." Researchers also assessed the impacts of individual dimensions of IT architectures such as the flexibility of IT resources (Duncan, 1995; Ray et al., 2005; Saraf et al., 2007). This research follows the conceptualization by Ross et al. (2006), who presented a more comprehensive analysis of a firm's enterprise IT architectures. They argued that multiple dimensions comprise an enterprise's IT architectures, and identified data, process, technology and applications to be the four components of IT architectures. Further, they identified IT integration and IT standardization as two of the key characteristics of a firm's IT architectures. Based on their conceptualization, this study focused on the impacts of these two aspects of supply chain IT architectures—i.e. integration and standardization—on supply chain capabilities and supply chain performance.

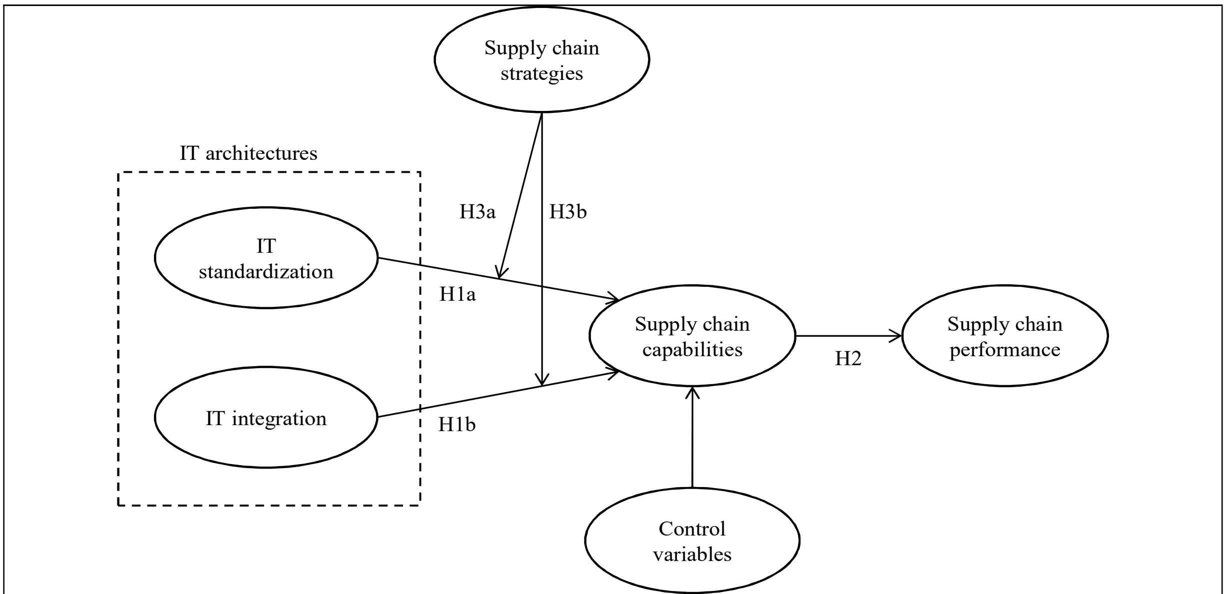

Figure 1 - Research model and hypotheses

Supply Chain Capabilities

Teece et al. (1997) argued that capabilities stress the adaptation, integration, and modification of organizational proficiencies, resources, and functional competencies both internally and externally as a response to uncertainty and volatility. Makadok (2001) also proposed that firms exploit the managerial mechanisms of resource-picking and capability building, to enhance their competitive advantages. Teece et al. (1997) defined capability-building as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (p. 516). From this point of view, firms develop their capacity to generate higher-order capabilities which they incorporate throughout their entire physical, cultural, and operational architecture (Grant, 1995; Teece et al., 1997).

Barney (2012) argued that supply chain management includes features which can help sustain a firm's competitive advantage. Supply chain capabilities comprise the ability of a firm to identify, apply, and incorporate internal and external resources in a manner that supports its supply chain operations (Amit and Schoemaker, 1993; Bharadwaj, 2000; Collis, 1994; Wu et al., 2006). A prior study classed supply chain capabilities as either efficiency-related or flexibility-related (Chen et al., 2009; Boyer and Lewis, 2002). Efficiency-related capabilities allow for better logistics performance at lower cost, while flexibility-related capabilities enable firms to retain their connections with supply chain partners while at the same time being responsive to consumer demand.

From the perspective of capability building, firms establish higher-order capabilities through a series of linked enterprise IT architectures with organizational processes and knowledge. If they can transform IT architectures that work for them into organizational capabilities, they can enjoy sustained success. Ross (2003) argued that developing enterprise IT architectures has the effect of spurring an evolving pattern of intertwined business strategies and IT capabilities. IT architectures are a source of competency that engenders superior supply chain capabilities, and these in turn comprise a firm's capacity to exploit internal and external resources in a manner that furthers its supply chain operations and its ability to maintain efficient production mechanisms in an uncertain and changing marketing environment. Supply chain capabilities are not readily duplicated by competitors so firms with such capabilities can find their niches and sustain competitive advantages. Without them, IT architectures may not boost supply chain performance.

Organizational resources comprise assets and capabilities, processes and attributes, and knowledge and information (Barney, 1991). Even if an organization's IT investment is valuable in that it enables the firm to identify opportunities and threats in supply chain networks, such IT systems are not rare. The ease with which these systems can be acquired or duplicated leaves firms vulnerable to losing their competitive advantage when competitors also implement similar IT systems. Thus, to establish competitive advantages, a firm should build for its IT systems superior architectures which reflect organizational strategies and thus cannot be easily imitated by others. Regarded as part of a firm's internal competency, IT architectures enhance the efficiency and flexibility of its supply chain network. Empirical evidence also suggests that inter-organizational information integration have positive impact on supply chain capabilities (Chen and Chiang, 2011; Rajaguru and Matanda, 2013; Roberts and Grover, 2012). Therefore, firms can leverage IT architectures to create higher-order capabilities, specifically supply chain capabilities, for sustainable competitive advantage. Therefore, this research hypothesizes:

H1a. *IT standardization is positively associated with supply chain capabilities.*

H1b. *IT integration is positively associated with supply chain capabilities.*

Firm Performance

Firms prioritize costs, flexibility, speed, time, and a high quality of customer service in connection with customer responsiveness and efficiency. Beamon (1999) contended that using single supply chain performance measurement is inadequate since it is not inclusive and it ignores other critical supply chain characteristics and strategic goals; therefore, he proposed a new framework for measuring supply chain performance, which covers resources (efficiency measurement), output (customer service measurement), and flexibility (response capabilities to a changing environment). Stank et al. (2001) investigated the relationship between logistical integration of the supply chain and performance; they suggested that managers could seek to exploit their supply chain processes to improve performance by identifying key customers' current and future supply chain needs and then developing a supply mechanism that satisfies those needs.

Supply chain capabilities can enhance operational and financial performance by lowering costs relative to competitors and allowing for a rapid response to customer needs. Empirical evidence suggests that certain supply chain capabilities have a positive impact on performance (See, for example, Liu et al., 2013; Parmigiani et al., 2011; Chen and Chiang, 2011; Qi et al., 2009; Wu et al., 2006; Sambamurthy et al., 2003). Thus, strengthening a firm's supply chain capabilities through its IT architectures directly impacts firm performance. Therefore, this investigation hypothesizes:

H2. *Supply chain capabilities have a positive impact on supply chain performance.*

Impact of Supply Chain Strategies on Supply Chain IT Architectures

To survive in a changeful business environment, firms in a supply chain network should have a clear idea about their supply chain strategies. Such strategies are commonly employed by firms who wish to maintain service levels by strengthening their relationship with customers. Satisfying customer needs is viewed as imperative for the creation of niche markets when manufacturers in a supply chain encounter intense competition either upstream or downstream. Fisher (1997) argued that firms can enhance performance if their supply chain strategies align with product characteristics. In Fisher's (1997) study, functional products required a lean supply chain while niche or novel products required an agile supply chain. We've adopted the view of Fisher (1997) because our focus is on operations strategies in the supply chain context. In our study, there are two different strategies in supply chain management, one labeled as a "lean strategy" and the other as an "agile strategy". A lean strategy refers to minimal waste from unneeded operations and inefficient operations to create niches of supply chain members (Narasimhan et al., 2006; Qi et al., 2009; Roh et al., 2014). It requires elimination of all forms of waste and develops a value chain network focused on lowering costs. Hence, a high level of IT integration may not be necessary when a lean strategy is implemented. In contrast, an agile strategy is about utilizing market knowledge to take advantage of opportunities and respond rapidly to customer needs in a volatile supply chain (Narasimhan et al., 2006; Qi et al., 2009; Roh et al., 2014; Fayezi et al., 2017). It improves firm performance by enhancing rapid adjustment capabilities to react to customer needs in a rapidly changing environment (Gligor et al., 2015). Greater IT integration with retailers, manufacturers, and suppliers is an enabler to sense changes and rapidly respond to their customers' needs.

The relationship between strategic alignment and performance has been widely addressed in previous literature. Chandler (1962) suggested that an organization's performance is dependent on the degree to which its strategy aligns with its design. Business-IT strategic alignment focuses on the degree of alignment between IT and business strategies, with the argument that better alignment generates better performance (Reich and Benbasat, 2000; Sabherwal and Chan, 2001; Wu et al., 2015). It contributes to the understanding of how organizations facing different supply chain strategies can choose better IT architectures to build supply chain capabilities and enhance performance. This implies that IT architectures should be matched with supply chain strategies that enhance particular supply chain capabilities. Thus, this study hypothesizes:

H3a**.** *Supply chain strategies moderate the relationship between IT standardization and supply chain capabilities such that the relationship is more positive if a lean supply chain strategy is implemented.*

H3b. *Supply chain strategies moderate the relationship between IT integration and supply chain capabilities such that the relationship is more positive if an agile supply chain strategy is implemented.*

Research Design and Methodology

Sample and Respondent Profile

We conducted an analysis of manufacturers in the Greater China area at the organizational level. To obtain a representative sample, the sampling frame is built from China Telecom's Guangzhou Yellow Pages for China-based businesses, and from the directories provided by the Ministry of Economic Affairs' Export Processing Zone Administration for businesses based in Taiwan. It is a representative sample for this empirical study because most manufacturers in the Greater China area are entrenched in global supply chains and hold prominent positions as major suppliers or contract manufacturers for original equipment manufacturers and original design manufacturers.

In the study, two questionnaires were developed as the survey instrument. One was designed for the businesses' IT departments in order to gather information on their IT architectures. The other questionnaire targeted the businesses' operations departments to evaluate their supply chain strategies, supply chain capabilities and firm performance. A panel composed of four academics familiar with the conceptual framework employed in this study and three practitioners– a general manager, an IT department manager, and an operations manager—reviewed the initial survey instrument for content validity. We then review their comments and modified the questionnaires accordingly to better suit our research. Since the original scales were in English, a professor of operations management and information management translated them into Chinese. Back-translation was applied to ensure that the meaning had not been altered.

The survey collected data from two informants in each of the organizations surveyed. An IT department manager was asked questions about IT standardization and IT integration (see Appendix A), while a supply chain manager was asked questions about supply chain strategies, supply chain capabilities, and firm performance (see Appendix B).

A pilot test was conducted with 20 respondents to pre-test questionnaires. After the pilot test, it was found that some IT department managers didn't answer several questions related to the supply chain performance construct. After discussing with them, we found that the questions were beyond their knowledge. Therefore, such questions were dropped from the questionnaire of IT architectures but were retained in the questionnaire of supply chain management.

Using the revised questionnaires, data were collected from manufacturers via mail, e-mail, or internet-based survey. A total of 200 firms were surveyed. Before doing the analysis, we dropped responses from firms with only one respondent or with missing data. The two questionnaires, which were completed by two informants in the same company, were combined into one questionnaire for analysis. The final sample included 162 responses, with 97 from China and 65 from Taiwan. The response rate was 81%. Table 1 presents profiles of the responding companies. The majority of the respondents were from the electronics & appliance (40%), mechanical (8%), textile (8%), printing (5%), and telecom (5%) industries. Respondents that represented less than 5% of the sample came from the plastics, chemicals, toys, software industries, among others. As for the total number of employees, 17% of them had less than 100 employees, 42% had 100-499 employees, 13% had 500-999 employees, and 28% had more than 1000 employees. As for firm sizes, 17% of them reported an annual sales of less than RMB$ 10 million in 2009, 40% reported RMB$ 10-50 million, 7% reported RMB$ 50-100 million, and 36% reported RMB$ 100 million.

Table 1 - Profiles of responding companies (n=162)		
Demographic	Items	Percentage (%)
Industry Type	Electronics & Appliance	39.60
	Metal, Mechanical & Engineering	8.05
	Textile & Apparel	8.05
	Printing	5.37
	Telecom	5.37
	Others	33.56
Total number of employees	less than 50	13.42
	51-100	4.03
	101-499	42.28
	500-999	12.75
	1001-4999	15.44
	5000 or more	12.08
Total sales of the company	less than RMB$ 10 million	17.45
	RMB$ 10-20 million	10.74
	RMB$ 20-50 million	28.86
	RMB$ 50-100 million	7.38
	RMB$ 100 million or more	35.57

Measure

We consulted the literature to before developing the measurement items for our questionnaires. Table 2 lists our constructs and operational definitions. We identified and modified existing scales to suit our research needs. The detailed measurement items for each construct can be found in Appendixes A and B. Respondents were asked to indicate the extent of their agreement with a given statement on a 5-point Likert scale where 1 indicates strong disagreement and 5 indicates strong agreement.

Rai et al. (2006) used second-order constructs to evaluate IT infrastructure integration and the integration of supply chain processes. In our study, IT standardization was viewed as a second-order construct comprising four sub-constructs including process, application, infrastructure, and data standardization. IT integration was also a second-order construct with four sub-constructs including process, application, infrastructure, and data integration. Scales for IT standardization and IT integration were adapted from Boh and Yellin (2007), Vickery et al. (2003), and Kim (2009).

On the other hand, supply chain capability is a second-order construct in two dimensions: efficiency capability and flexibility capability. The scale we used for measuring supply chain capabilities was adapted from previous literature (Kim, 2009; Kristal et al., 2010; Rosenzweig et al., 2003). Supply chain performance consisted of customer service, process improvement, operating cost and financial performance, and a scale for the performance scale was adapted from previous literature (Brewer and Speh, 2000; Qi et al., 2009). Supply chain strategies included a lean strategy and an agile strategy. The scale for measuring such strategies was adapted from Qi et al. (2009). This investigation also had two control variables, namely demand uncertainty and supply uncertainty, which were adapted from Chen and Paulraj (2004) to express environmental uncertainty. The two control variables were included in our research because supply chain capabilities can reduce impact of uncertainty regarding demand and supply through matching demand to supply in the supply chain network.

Table 2 - Construct definitions

Construct & sub-construct	Operational definition	Reference	Total items
IT Standardization: The degree to which a focal firm has the similarity in function, interface, functionality, logic or formats of the underlying elements			
Process Standardization	The extent to which the process is standardized	Boh and Yellin (2007); Vickery et al. (2003); Kim (2009)	6
Data Standardization	The extent to which data format is standardized		9
Infrastructure	The extent to which the infrastructure of supply chain members is standardized		5
Standardization	The extent to which application software of supply chain members is standardized		
Application	The extent to which the process is standardized		6
Standardization	The extent to which data format is standardized		
IT Integration: The degree to which a focal firm has the ability to link elements in one domain to another using IT systems			
Process Integration	The extent to which the supply chain processes are integrated	Boh and Yellin (2007); Vickery et al. (2003); Kim (2009)	6
Data Integration	The extent to which the databases of supply chain members are integrated		9
Infrastructure Integration	The extent to which the technology infrastructure is integrated		5
Application Integration	The extent to which application software of supply chain members is integrated		6
Supply chain performance: The degree to which a focal firm has superior operational performance and financial performance relative to its competition			
Customer Service	Performance in customer service such as product quality and delivery speed	Qi et al. (2009)	5
Process Improvement	Performance in supply chain process such as process improvement and new product development	Brewer and Speh (2000)	3
Financial performance	Return and growth performance such as ROI	Qi et al. (2009)	6
Operating Cost	Performance in operating costs, such as manufacturing costs, shortage costs	Qi et al. (2009)	5
Environmental uncertainty: The degree of which a focal firm faces demand and supply uncertainty			
Demand Uncertainty	Demand uncertainty is measured using fluctuations and variations in demand	Chen and Paulraj (2004)	5
Supply Uncertainty	Supply uncertainty includes indicators that meet manufactures' requirements and quality	Chen and Paulraj (2004)	2
Supply Chain Strategies: Which supply chain strategy is closely linked with product characteristics implemented by a firm?			
Lean Supply Chain Strategy	Building a value stream to eliminate all waste to create niche of supply chain members by operating cost-effectively	Qi et al. (2009)	6
Agile Supply Chain Strategy	Using market knowledge to exploit profitable opportunities and respond rapidly to customer	Qi et al. (2009)	4

In addition, it was necessary to identify what types of supply chain strategies were implemented by the firms. An index was established by calculating the difference between the mean value of a lean strategy and the mean value of a lean strategy in a response. A positive index value indicated the firm put emphasis on a lean supply chain strategy; a negative index value meant the firm inclined toward an agile strategy. It was discovered that of all respondents, 59 adopted an agile strategy and 103 adopted a lean strategy.

Analysis Strategy

Our empirical model was tested using SPSS18.0 for Windows and SmartPLS 2.0M3 software package. SPSS was used to conduct descriptive analysis and to test data reliability and validity, while SmartPLS estimated paths in our research model and tested our hypotheses. We used a bootstrapping procedure to estimate the significance of path coefficients. Multivariate means, which are based on the summated means values of items, were used to measure each of the sub-constructs as reflective indicators. The higher-order factors in our model were estimated using these reflective indicators.

Common Method Variance

Common method variance becomes a serious concern when the dependent and independent variables are both derived from a single respondent from an organization (Podsakoff and Organ, 1986). To avoid common method variance, this study split our survey into two questionnaires each targeting a different informant from one organization. Questions about independent variables, including IT standardization and IT integration, were answered by IT managers of organizations, while questions about dependent, moderating, and control variables were answered by supply chain managers. However, this investigation also assessed the potential for common method variance in the following way.

First, an analysis was made based on Harmon's single-factor test of common method variance. If common method variance had a major impact on our study, factor analysis would reveal a single factor, or one overall factor would underlie the majority of covariance in the dependent or explanatory variables (Podsakoff and Organ, 1986). Principal factor analysis of all the items in this study resulted in three factors with eigenvalues greater than 1.0. The three factors accounted for 76% of the total variance, with the largest factor accounting for 45%. No single factor emerged and no general factor was able to account for the bulk of the variance; thus, common method variance should not be a major issue. We then applied confirmatory factor analysis (CFA) to Harman's single-factor model (Sanchez and Brock, 1996) for a more in-depth assessment of common method variance. The model's fit indices of $\chi2$ (77) = 521.067, NFI = 0.731, GFI = 0.648, RMSEA = 0.189 and SRMR = 0.062 were unacceptable and were worse than the fit indices of the measurement model to a significant degree. As we had expected, these tests suggested that a single factor was not acceptable; thus, common method variance was not a major concern for our research.

Results

Reliability and Validity

After collecting the data, we performed several analyses to test for reliability and validity of the constructs (Table 3). All of the scales demonstrated acceptable reliability above 0.70 (Hair et al., 1995). Also, this study calculated the internal composite reliability, and the reliability for all variables exceeded the 0.70 threshold.

Content validity was confirmed through an examination of the literature, an evaluation of the currently existing constructs, and a review of those constructs by experts in the field. We examined the average variance extracted (AVE) of each construct to estimate its convergent validity. Because each construct's AVE exceeded 0.50, our measures satisfied the heuristics for confirmation of convergent validity (Barclay et al., 1995). Next, we checked for discriminant validity via the method described by Fornell and Larcker (1981), where the threshold for discriminant validity is reached when the variance that a construct shares with its indicators exceeds that shared with other constructs in the model. Table 3 shows that the square root of the average variance extracted (0.685 to 0.931) was greater than any corresponding correlation; thus, the construct met the criterion for discriminant validity.

Table 3 - Correlations among constructs (n=162)

Constructs	Mean (SD)	Cronbach's alphas	1	2	3	4	5	6
IT standardization	3.150 (0.776)	0.948	0.963/ 0.931					
IT integration	3.518 (0.731)	0.922	0.891***	0.944/ 0.900				
Supply chain capabilities	3.742 (0.547)	0.716	0.324***	0.310***	0.874/ 0.881			
Supply chain performance	3.662 (0.504)	0.814	0.242**	0.216*	0.523***	0.875/ 0.799		
Demand uncertainty	3.027 (0.732)	0.774	0.115	0.040	0.322**	0.170	0.814/ 0.685	
Supply uncertainty	3.741 (0.544)	0.840	0.092	0.064	0.340***	0.263**	0.140	0.923/0.926

Notes: The values below the diagonal are correlations. The diagonal values in italics to the right of the slash are the square root of the average variance extracted for each construct; the values to the left are the composite reliabilities. *p<0.05, **p<0.01, ***p<0.001.

Hypotheses Testing

We used a bootstrap analysis with 2000 subsamples to estimate the significance of path coefficients. Table 4 shows the path estimates of the structure equation model. Model 1 represents the full model, which did not include any impact of supply chain strategies. Model 2 included the impact of a lean supply chain strategy, and Model 3 addressed the impact of an agile supply chain strategy. Hypothesis 1a predicts that IT standardization is positively associated with supply chain capabilities. The result revealed that IT standardization did not significantly predict supply chain capabilities (β =0.080, *p*>0.05, Model 1). Hypothesis 1b predicts that IT integration is positively associated with supply chain capabilities. The result revealed that IT integration did not significantly predict supply chain capabilities (β =0.210, *p*>0.05, Model 1). Hypothesis 2 proposes that supply chain capabilities are positively related to supply chain performance. The results demonstrated that supply chain capabilities significantly predicted supply chain performance under either supply chain strategy (β = 0.497, *p*<0.001, Model 1; β = 0.418, *p*<0.001, Model 2; β = 0.598, *p*<0.001, Model 3).

Hypothesis 3a and 3b predict that the focus of IT architectures, i.e. IT standardization and IT integration, differs under different supply chain strategies. First, the result revealed that the path of supply chain capabilities on IT standardization under a lean strategy was significant (β= 0.267, *p*<0.05, Model 2). In contrast, the path of supply chain capabilities on IT standardization under an agile strategy was not significant (β= -0.285, *p*>0.05, Model 3).

This study found that the interaction between IT standardization and a lean strategy had impacts on supply chain capabilities, thus supporting H3a. Second, the paths of supply chain capabilities on IT Integration under lean and agile strategies were tested respectively. The result revealed that the path of supply chain capabilities on IT integration under a lean strategy was not significant (β=0.056, *p*>0.05, Model 2). In contrast, the path of supply chain capabilities on IT integration under an agile strategy was significant (β= 0.517, *p*<0.05, Model 3). The results revealed that an agile strategy interacted with IT integration to influence supply chain capabilities, thus supporting H3b.

Table 4 - The path estimates of structure equation models

Path estimates and R-squares	Full Model (M1)	Lean strategy group (M2)	Agile strategy group (M3)
Path estimates			
IT standardization→supply chain capabilities	0.080	0.267*	-0.285
IT integration→supply chain capabilities	0.210	0.056	0.517*
Supply chain capabilities → supply chain perf.	0.497***	0.418***	0.598***
IT standardization → supply chain perf.	0.126	0.224	-0.089
IT integration → supply chain perf.	-0.050	-0.230	0.288
Demand uncertainty → supply chain capabilities	0.265***	0.281***	0.296*
Supply uncertainty → supply chain capabilities	0.282***	0.234***	0.402***
R-squares			
Supply chain capabilities	0.272	0.298	0.347
Supply chain performance	0.280	0.197	0.474

Note: The respective sample sizes of M1, M2 and M3 are 162, 103, and 59.
The t-values are estimated by bootstrapping procedures. *p<0.05, **p<0.01, ***p <0.001 (one-tailed test)

This study followed the guidelines provided by Aiken and West (1991) in plotting the interactions to better understand the moderating effect. The interactions were plotted one standard deviation above and below the mean for IT standardization (see Figure 2) and IT integration (see Figure 3). Figure 2 shows that IT standardization has a greater impact on supply chain capabilities when firms tend to implement a lean strategy. As shown in Figure 2, when IT standardization is high, having a lean strategy is more beneficial to supply chain capabilities than an agile strategy. Figure 3 shows that IT integration has a greater impact on supply chain capabilities when firms tend to implement an agile strategy. As shown in Figure 3, when IT integration is high, having an agile strategy is more beneficial to supply chain capabilities than a lean strategy.

One indicator of the path models' predictive power is the amount of variance they explained (see Table 4). The results showed that the models explained more than 27.2% (ranging from 27.2% through 34.7%) of the variance in supply chain capabilities. Moreover, more than 19.7 % (ranging from 19.7% through 47.4%) of the variance in supply chain performance could be explained by supply chain capabilities.

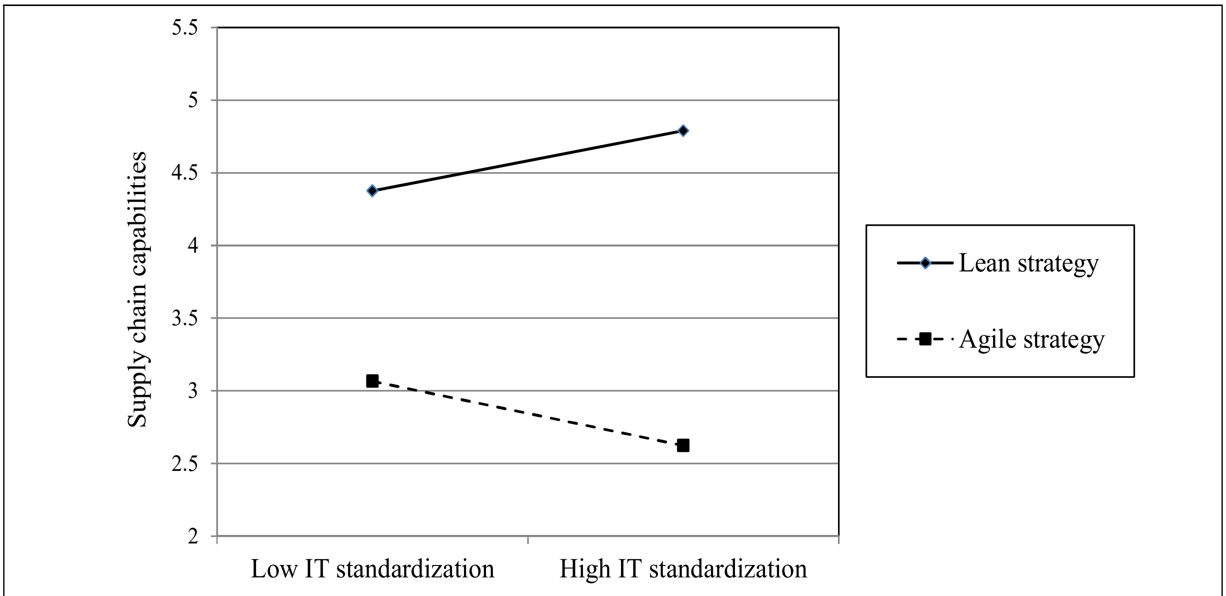

Figure 2 - Interaction plot of IT standardization and supply chain strategies on supply chain capabilities

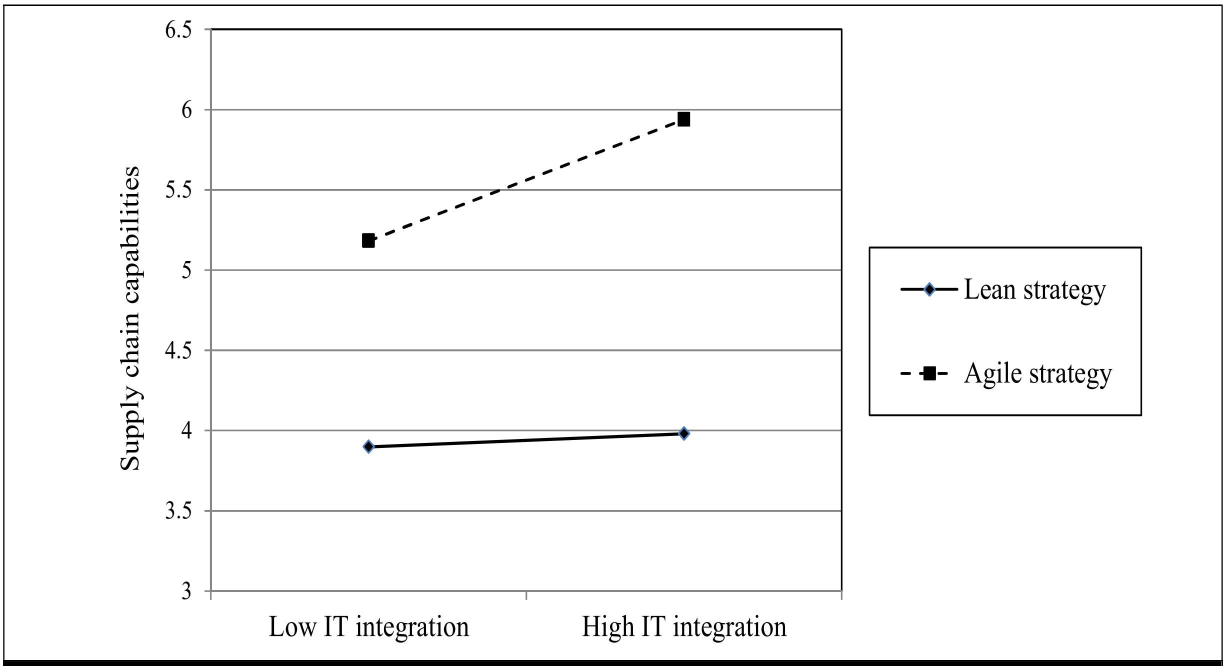

Figure 3 - Interaction plot of IT integration and supply chain strategies on supply chain capabilities

Discussion and Managerial Implications

Our goal was to assess how IT architectures affect supply chain capabilities and firm performance. First, firms may leverage IT to develop supply chain capabilities, which will result in higher supply chain performance. This result verified the capability-building process. Second, integration and standardization of IT architectures for supply chain management had different impacts on supply chain capabilities when different supply chain strategies were adopted. This result verified the strategic alignment theory of IT use. Agile strategies call for higher IT integration to enhance supply chain capabilities for fast response, while lean strategies can be supported by the standardization of IT architectures, and no tight integration is required.

Developing a value chain network with a focus on cost reduction is the first priority in a lean strategy. It can reduce the complexity of skills needed for maintaining firms' IT systems to standardize different IT systems across supply chain partners. Prior research claimed that IT standardization is associated with an increase in overall efficiency (Lillrank, 2003). IT standardization enables firms to coordinate their partners' activities so as to meet predictable demand at the lowest cost. That is, IT standardization is an enabler to supply chain capabilities because lean strategy requires elimination of all forms of waste. IT standardization has more impact on a firm's IT architectures when a lean supply chain strategy is implemented.

On contrast, an agile supply chain strategy is about effective manufacturing in response to a volatile or changing market. Greater IT integration with retailers, manufacturers, and suppliers is an enabler to sense the change and respond rapidly to customer needs. Previous research has shown that firms tend to establish value chains and links between organizations by incorporating the totality of products, services, and IT systems into a single integrated framework to maintain success (Kettinger et al., 1994; Rajaguru and Matanda, 2013; Wheeler, 2002; Wu et al., 2006). Moreover, IT standardization restricts local firms' IT innovation so it results in a less optimal local solution (Ross, 2003), which may limit the ability to respond to customer needs. That is, when a firm implements an agile strategy, then IT integration is an enabler to its supply chain capabilities. IT integration has more impact on a firm's IT architectures when an agile supply chain strategy is implemented.

The study adds in multiple ways to the literature examining supply chain IT architectures. First, we extend the assessment of IT impacts by refocusing on the IS antecedents. Based on the industrial organization (IO) economic view of a firm, earlier IS research has primarily examined performance impacts by assessing the returns on IT investments (e.g., Byrd and Marshall, 1997; Barua et al., 1995; Francalanci and Galal, 1998; Lee and Barua, 1999; Loveman, 1994). To offer a more nuanced understanding of the IT impact dynamics, more recent research has examined alternative facets of IT, such as the degree to which IT systems are being used (Mishra and Agarwal, 2010; Devaraj and Kohli, 2003), or aspects of IT design (Armstrong and Sambamurthy, 1999; Broadbent et al., 1999a; Byrd and Turner, 2001; Ray et al., 2005; Saraf et al., 2007). In the supply chain literature there has been a greater focus on the antecedents that assess the functionalities or capabilities of IT. We contribute to this domain of research by showing the consequences of two dimensions of IT architectures—IT integration and IT standardization—on supply chain performance. Unlike prior research which focused on IT functionalities and IT usage, our study extends the repertoire of IT as a precursor to supply chain capabilities and firm performance.

Our study also extends prior research on IT-enabled capability development by highlighting how firms may leverage digital technologies to develop capabilities across supply chains (Barney, 1991; Teece et al., 1997; Eisenhardt and Martin, 2000; Makadok, 2001). In doing so, we add to the literature studying just-in-time (JIT), customer–supplier partnering, and other IS-enabled capabilities (Banker et al., 2006), and information-related capabilities (Barua et al., 2004) in the supply chain domain, and technological opportunism and technological sophistication within the procurement domain (Mishra and Agarwal, 2010). The research contributes to this literature by showing the different impacts of supply chain strategies in capability-building dynamics.

With products at the maturity stage of life cycle, which means stable demand and product standardization, firms will work to develop and maintain a stable production schedule that leads to reductions in cycle time, smaller inventories, and enhanced supply chain performance in general. That is, they require a lean supply chain strategy that reflects the stable business environment. Also, IT standardization, which is relatively loose coordination in IT architectures, is implemented for reduced variability and dramatically increased throughput and efficiency. In a relatively stable environment, IT standardization can bring advantages by eliminating unnecessary waste even though imposes restriction on a firm's IT innovation.

On the contrary, an agile supply chain strategy is implemented when product life cycle is short and markets are changing quickly. The strategy provides customer-driven products with unique features to support a high level of customer service. IT integration, which is relatively tight coordination in IT architectures, is implemented for increased transparency and agility. Moreover, an integrated IT system among supply chain members can provide managers with better information for decision-making. Given that, a firm may opt against IT standardization in order to maintain its agility because IT standardization restricts IT innovation. Agility reduction in one single company will bring down the overall performance and advantages of its supply chain in the highly competitive business environment because, according to the theory of constraints, overall agility of a supply chain network is decided by the minimal agility of a member.

Lately, some have argued that IT may be an inhibitor to firms with agile operations (Lu and Ramamurthy, 2011). Our results may serve as evidence for such argument. That is, our research argues that a firm's IT architecture must be matched with its supply chain strategies to realize better performance. Without alignment between IT architecture and supply chain strategies, a firm's IT investment may not be worthwhile. Organizations employing different supply chain strategies should be more discerning in order to adopt an IT architecture that works best for them; otherwise, just like previous research argued, IT investments do not enhance firm performance.

Finally, the result of our study showed that supply chain capabilities improved a firm's performance through its IT architectures; the discovery is consistent with the capability building perspective. IT resources are not rare and can be easily imitated, and firms should deploy idiosyncratic, valuable, and inimitable capabilities. It may no longer be enough for firms to rely solely on IT resources to enhance performance; instead, they should focus more on supply chain capabilities.

Conclusions

We have made theoretical and empirical contributions to enrich supply chain literature in several important ways. First, we highlighted an integrated perspective on IT and business capabilities and strategies. Second, the conceptual framework was empirically tested by collecting data from the Greater China area. Finally, we investigated the impact of IT architectures on firm performance. In conclusion, our results revealed that under a lean strategy, IT standardization had more impact on IT architectures and in turn enhanced supply chain capabilities and firm performance, whereas IT integration had more impact on IT architectures under an agile strategy. The results also showed that supply chain capabilities were an enabler that enhanced supply chain performance through well-suited IT architectures.

While this study contributes to the literature through important managerial implications, it is also subject to limitations that indicate a need for further study. While our sample is comprehensive in covering major industries in the Greater China region, its geographical reach is relatively small. More can be done to collect data from other regions or countries, compare them with this study's results, and refine the research model to gain greater insights. In particular, the researchers may want to test our model on North American and European firms to see how closely their data parallel or diverge from our results. Second, we examined the role of two specific supply chain strategies—lean and agile—in the impact of IT architectures. Future research may investigate other supply chain strategies, such as implementing lean and agile strategy at the same time. More in-depth knowledge about supply chain strategies can help researchers and managers understand the interaction between IT architectures and strategies.

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Appendixes

Appendix A: The Questionnaire Relative to IT Architectures for IT Managers

A1. Enterprise Architecture Integration

Integration is the ability to link elements in one domain to another. High integration implies that there are comprehensive, efficient, well-coordinated and transparent linkages of an element in one domain with the corresponding elements in another domain. Please rate on a scale of 1 to 5 regards the following in your organization. The following items are rated from 1 = very low to 5 = very high.

Process integration

1. Integration of demand planning processes with your customers
2. Integration of demand planning processes across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
3. Integration of demand planning processes with your suppliers
4. Integration of manufacturing processes with your customers
5. Integration of manufacturing processes with your suppliers
6. Integration of demand fulfillment processes with your customers

Application integration

1. Integration of IT applications for demand planning (i.e., bar coding and RFID) with your customers
2. Integration of IT applications for demand planning (such as data analytics) across marketing sales, manufacturing, supply chain, and purchasing departments
3. Integration of IT applications for demand planning (such as data analytics) with your suppliers
4. Integration of IT applications for production planning with your customers
5. Integration of IT applications for production planning with your suppliers
6. Integration of IT applications for demand fulfillment (such as, for capacity planning, CAD, and manufacturing) with your customers

Infrastructure integration

1. Integration of IT infrastructure (e.g. network and storage, and IT service staff) across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
2. Integration of IT infrastructure across supply chain department of your firm and your partner’s supply chain department
3. Integration of IT infrastructure across your customers and supply chain departments of your firm
4. Integration of IT infrastructure across your customers and marketing department of your firm
5. Integration of IT infrastructure across your marketing department and supply chain department of your partners’ firm

Data integration

1. Integration of production data across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
2. Integration of production data with your suppliers
3. Integration of production data with your customers
4. Integration of demand forecast across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
5. Integration of demand forecast with your suppliers

6. Integration of demand forecast with your customers
7. Integration of design data across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
8. Integration of design data with your suppliers
9. Integration of design data with your customers

A2. Enterprise Architecture Standardization

Standardization refers to the similarity in function, interface, functionality, logic or formats of the underlying elements. High standardization implies that an individual in one domain has to spend the least possible amount of effort or time to interpret the corresponding element in another domain. Please rate on a scale of 1 to 5 regards the following in your organization. The following items are rated from 1 = very low to 5 = very high.

Application standardization

1. Standardization of IT applications for demand planning (i.e., bar coding and RFID) with your customers
2. Standardization of IT applications for demand planning (such as data analytics) across marketing sales, manufacturing, supply chain, and purchasing departments
3. Standardization of IT applications for demand planning (such as data analytics) with your suppliers
4. Standardization of IT applications for production planning with your customers
5. Standardization of IT applications for production planning with your suppliers
6. Standardization of IT applications for demand fulfillment (such as, for capacity planning, CAD, and manufacturing) with your customers

Process standardization

1. Standardization of demand planning processes with your customers
2. Standardization of demand planning processes across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
3. Standardization of demand planning processes with your suppliers
4. Standardization of manufacturing processes with your customers
5. Standardization of manufacturing processes with your suppliers
6. Standardization of demand fulfillment processes with your customers

Infrastructure standardization

1. Standardization of IT infrastructure (e.g. network and storage, and IT service staff) across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
2. Standardization of IT infrastructure across supply chain department of your firm and your partner's supply chain department
3. Standardization of IT infrastructure across your customers and supply chain departments of your firm
4. Standardization of IT infrastructure across your customers and marketing department of your firm
5. Standardization of IT infrastructure across your marketing department and supply chain department of your partners' firm

Data standardization

1. Standardization of production data across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
2. Standardization of production data with your suppliers

3. Standardization of production data with your customers
4. Standardization of demand forecast across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
5. Standardization of demand forecast with your suppliers
6. Standardization of demand forecast with your customers
7. Standardization of design data across marketing, sales, manufacturing, supply chain, and purchasing departments of your firm
8. Standardization of design data with your suppliers
9. Standardization of design data with your customers

Appendix B: The Questionnaire Relative to Supply Chain Management for Supply Chain Managers

B1. Supply Chain Capabilities

Please rate on a scale of 1 to 5 regards the following in your organization. The following items are rated from 1 = very low to 5 = very high

Efficiency Capability

1. Our joint capability to manufacture products at lower costs of production
2. Our joint capability to lower administrative overheads
3. Our joint capability to offer lower priced products
4. Our joint capability to consistently lower order cycle time from order entry to delivery
5. Our joint capability to increase worldwide delivery capacity

Flexibility Capability

1. Our joint capability to provide dependable on-time delivery
2. Our joint capability to rapidly change product mix (types)
3. Our joint capability to meet urgent delivery
4. Our joint capability to integrate new members
5. Our joint capability to offer reliable products that meet customer needs
6. Our joint capability to offer customer service that meet customer needs
7. Our joint capability to offer product support and assurance that meet customer needs
8. Our joint capability to offer products that conform to design specifications

B2. Supply Chain Strategies

The following statements are descriptions of supply chain strategies. To what extent do you agree that the supply chain of your company's major product/product mix has the following characteristics? The following items are rated from 1 = Strongly Disagree to 5 = Strongly Agree.

Lean Supply Chain Strategy

1. Our supply chain supplies predictable products
2. Our supply chain reduces any kind of waste as much as possible
3. Our supply chain reduces costs through mass production
4. Our supply chain needs to maintain a long and rigid relationship with a small number of suppliers
5. Our supply chain selects the suppliers based on their performance on cost and quality
6. Our supply chain structure seldom changes

Agile Supply Chain Strategy

1. Our supply chain always faces the volatile customer demand
2. It is necessary for our supply chain to maintain a higher capacity buffer to respond to volatile market
3. Our supply chain provides customer with personalized products
4. Our supply chain selects the suppliers based on their performance on flexibility and responsiveness

B3. Supply Chain Performance

How does your company perform compared relative to your major competitors? Please rate the following from 1 = Much Worse than industry competitor to 5 = Much Better than industry competitors.

Customer Service

1. Overall product quality
2. Customer service level
3. Responsiveness to customers
4. Delivery speed
5. Delivery dependability

Process Improvement

1. Improvement of operational process
2. Development of new product and service
3. Partner relationship management

Operating Cost

1. Unit manufacturing cost
2. Inventory turnover
3. Overall labor productivity
4. Stock-out cost
5. Obsolescence cost

Financial Performance

1. Return on investment
2. Return on Sale
3. Market share
4. Growth in ROI
5. Growth in ROS
6. Growth in market share

B4. Environmental Uncertainty

The following descriptions are about your company's supply chain environment, to which extent you agree with the descriptions. The following items are rated from 1 = Strongly Disagree to 5 = Strongly Agree.

Demand Uncertainty

1. Our master production schedule has a high percentage of variation in demand
2. Our demand fluctuates drastically from week to week
3. Our supply requirements vary drastically from week to week
4. We keep weeks of inventory of the critical material to meet the changing demand
5. The volume and/or composition of demand is difficult to predict

Supply Uncertainty

1. The suppliers consistently meet our requirements
2. The suppliers produce materials with consistent quality

About the Authors

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